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LARCH SAWFLY INVESTIGATIONS IN MINNESOTA IN 1952

By

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SPECIAL REPORT

LARCH SAWFLY INVESTIGATIONS IN MINNESOTA IN 1952

A. T. Drooz 1/

Summary

Ecological and biological investigations on the larch sawfly, Pristiphora erichsonii (Htg.), were resumed in Minnesota in 1952. A survey of 425,220 acres of the tamarack type revealed complete defoliation on 150,000 acres and partial defoliation on an additional 141,000 acres.

During the previous outbreak in Minnesota one billion board feet of tamarack was reported killed by this pest, but currently no tamarack mortality can be directly attributed to it.

Population dynamics are being studied, utilizing branch samples for larval and oviposition investigations, frass weights for larval activity, and counts of cocooning populations in relation to different degrees of defoliation. Due to the preliminary nature of this work comparisons are restricted, but certain relationships that have been brought to light bear more comprehensive study. Among these are the relationship of the critical number of curled tips (oviposition sites) and subsequent defoliation; quantities of frass dropped at certain fifth-instar population levels; and the possibility of predicting the degree of defoliation by the numbers of cocoons found during spring or late summer collections.

1/ The writer is indebted to field aides L. G. Beckwith for assistance on the field and laboratory phases of this study and J. A. Miller for aid in making collections during the field season. Thanks are also due to the Minnesota State Entomology Department, the Naugatuck Chemical Division of the U. S. Rubber Co., and the Dominion Parasite Laboratory at Belleville, Ontario. R. R. Lejeune and J. A. Muldrew, of the Laboratory of Forest Biology, at Winnipeg, Manitoba, have been of considerable help in connection with the whole larch sawfly program, as well as with studies of the natural immunity of the sawfly to parasitization. Thanks are also due to the Dominion Laboratory of Insect Pathology at Sault Ste. Marie, Ontario, for analyzing larch sawfly material for entomophagous diseases.

At present, parasites do not appear to be playing an important role in the control of this pest. Only two species are numerous; these are Hemolynx tuntiredinis Morley and Perna eclecta (Weig.). The host has developed such a high degree of resistance to parasitism by the former that only about 16 percent of the attacks were successful in 1952. Entomophagous diseases of the larvae have exerted a modest amount of control.

In an effort to prevent shoot elongation and thus preclude oviposition, a growth-inhibiting amide, maleic hydrazide, was used. The tests with this material were negative, probably due to the low concentrations of the chemicals that were applied to the trees. Additional tests are planned.

When beginning a study of a defoliator, the knowledge of certain of its characteristics is of assistance to the general program. Consequently, head capsule measurements of the larvae in the five instars were made and the duration of each larval stadium was determined. During the latter study the quantity of frass produced by the larvae in their developmental stages was also determined.

Introduction

The larch sawfly is an oligophagous, probably wholly parthenogenetic insect whose distribution is limited to the regions of the world where its hosts, Larix spp. may be found. Its presence in North America was first noted in 1880 when specimens were sent by C. S. Sargent, director of the Arnold Arboretum, Brookline, Massachusetts, to H. A. Hagen, of the Museum of Comparative Zoology, Harvard University (Packard 1890).

The destructive capabilities of this pest were first observed in Maine during the summer of 1882 when extensive defoliation of tamarack resulted from larval feeding. At about the same time the insect became epidemic in northeastern United States and eastern Canada.

Although conjectural evidence has been presented to indicate that this sawfly is a native pest, general acceptance of this postulate awaits more adequate research. The larch sawfly attracted attention in Minnesota in 1909. The destruction of one billion board feet of tamarack, between 1910 and 1926 was attributed to this pest (Graham 1939).

It is difficult to date an insect outbreak, but unpublished forest insect records of considerable extent in Minnesota from 1935 to 1952 point out that the larch sawfly was present in noticeable numbers during that time and that a population upsurge became manifest in 1946, erupting into the current outbreak between 1947 and 1949. This epidemic (Fig. 1) is concurrent with one in Manitoba and Saskatchewan.

Objectives

The objectives of this study are to develop information regarding the population dynamics of the larch sawfly, factors affecting the population, and the effects of the insect on tamarack. With this information it is believed that the genesis, course, and results of larch sawfly epidemics will be better understood, so that when necessary proper preventive or remedial measures may be taken.

Methods of Study

During the 1952 field season in northern Minnesota, two plots were established on different tamarack sites for detailed ecological study and 23 plots were utilized to initiate the collection of data on population trends, defoliation, and parasitism.

At each of the two ecological study plots 15 trees in a line were paint-numbered. Under the crown of each tree were installed two circular frass traps, each one covering two square feet. It was intended that frass collections be taken every two days at both sites, but frass drop commenced so late and was so light at one test area it was considered impractical to follow the original plan; consequently in this case only the record of the average weight of oven-dried frass per square foot was kept. Five trees were selected in both of these sites for weekly analyses of the numbers of larvae per instar and the numbers of curled tips (indicative of oviposition) found on a two-branch sample at the mid-crown level of each tree. It was also intended that records would be kept of the rates of oviposition at both sites, but trees of small enough size were found at only one site. Here, branches on five trees were tagged for observation. Newly curled tips were counted and clipped at approximately three-day intervals until oviposition activity slowed down; then longer intervals were used.

A collection of 517 cocoons provided material to note adult emergence. These cocoons were put, individually, into number 000 gelatin capsules to prevent contamination and at night they were held in a cool, moist subcellar, where the temperature ranged between 58 and 60 degrees F. At approximately 8:00 a.m. the cocoons were placed in an insulated cabinet on the screened porch of the field laboratory where shade and moderate temperatures were available. The 5:00 p.m. temperature in the cabinet averaged 70 degrees F.

At least one-half inch of new shoot is necessary for oviposition. An experiment was conducted utilizing the growth retarding auxin, maleic hydrazide, to inhibit shoot elongation and thus prevent oviposition. The water emulsion concentrate, maleic hydrazide-40, was diluted to provide the concentrations of 0.125, 0.250, and 0.337 percent maleic hydrazide that were applied with a garden sprayer in three replications on trees 4.6 to 9.3 feet high, until run-off occurred.

A late summer cocoon collection was made in connection with the larch sawfly ground survey. The cocoons were placed in number 000 gelatin capsules so that cocoon parasites would not infest other cocoons, and to isolate diseased prepupae. These cocoons were kept at 40 degrees F. in a commercial food locker until the middle of January, 1953, at which time they were removed to the laboratory where quantitative information on entomophagous parasites and diseases was developed.

Larval head capsules were measured to the nearest hundredth of a millimeter with the aid of an eyepiece micrometer scale. Measurement of 20 head capsules was sufficient to give statistically sound results.

Data were kept on the duration of each larval stadium, and also on the oven-dried weight (O.D.W.) of frass produced by the larvae in the first three instars grouped, and by those in each of the fourth and fifth instars. To minimize mortality due to handling of the newly hatched larvae, the bases of the curled tips containing the sawfly eggs were placed in vials of water so that the larvae, as soon as they hatched, could feed without disturbance. Frass was collected daily and as the larvae passed through an ecdysis they were placed in a different rearing container.

Results

Maleic hydrazide-40

Maleic hydrazide-40, a new growth-inhibiting auxin, was applied to sapling tamaracks on May 16, 1952. Periodic examination was made during the summer to determine the effect of the application. The trees were cut for measurement on July 17, 1952. No adverse effects to the foliage were observed. Shoot elongation commenced normally the first week of June. Examination of the data indicated negative results and a statistical analysis was deemed unwarranted. Experiments utilizing higher concentrations of the auxin are planned for 1953. The data (Table 1) apply to the tests that were made on May 16, 1952.

Frass drop studies

Frass drop records may serve as useful criteria to evince the proper timing and effects of control measures. An experiment was designed to indicate the patterns of frass drop at two different sites during the period of larval activity. One site, Garfield Lake, had a high larval population, while the population at the Boulder Lookout plot was comparatively light. Much time was consumed searching for suitable study areas, and as a result the frass trays were established an estimated two weeks too late at the former location. With one important exception, all the collections at Garfield Lake were made at 48-hour intervals. Due to heavy rains it was not practicable to collect frass on July 2. The peak of frass drop possibly would have fallen on this date (Fig. 2). Regular examination of the frass trays at the Boulder Lookout plot showed that little frass was falling over either two-day or weekly periods. Therefore, only the total accumulation was measured.

Analysis of the data indicated that it may be possible to index the fifth-instar population (Table 2). It would be venturesome to draw conclusions from this initial work; however, it if were not for the collection of July 4, the number of fifth-instar larvae per collection might well reflect the proportion of frass trapped. Unfortunately, on July 4 the pressure of more immediate duties and the temporary loss of a worker, who was conferring with State entomologists, prevented handling the living larvae as expeditiously as was necessary, and it is believed that many of them escaped. Cloth bags will be used in 1953 in an effort to reduce the losses from this source.

There were highly significant differences between trees at both sites, as might be expected, but within-tree differences were small (Table 3). Additional trees (plots) could be used to resolve these differences, but it is believed that sufficient information for the problem on hand can be garnered with the present system. Since there was little within-plot variation, especially at the Garfield Lake plot where total defoliation occurred, only a single line of frass traps will be used in the future.

Branch studies

In an effort to observe the dynamics of the larval population at both study areas, two branches were removed weekly from each of five tamaracks at the middle third of the crown. Numerous difficulties were encountered in this line of work, some of them being: the brashness of tamarack branches made climbing hazardous; the emergence of adult sawflies over the course of two months so that all five larval stages could be found feeding within a couple of weeks after the new shoots had elongated.

In conjunction with a study of the larval population, a count was made of the number of curled tips which represented the sites of oviposition. A tentative statement in regard to the ratio of curled tips to percent defoliation may be made. Where defoliation was complete, 20 percent of the new shoots were curled, but at the area where defoliation averaged 30 percent, this occurred on only 5 percent of the new shoots. If these data are corroborated in 1953, additional collections will be made from trees having various amounts of defoliation to determine if a correlation exists between curled tips and feeding potential. If such a correlation is indicated, it may be possible to predict the necessity of controlling the insect in stands where a critical number of shoots have been utilized for oviposition. If the adult population is high the only factor that may control defoliation is the length of the shoot available for oviposition. Shoots attacked after July 10, 1952 did not assume the characteristic curl. Apparently they are hardened sufficiently six weeks after the initiation of growth to preclude this type of damage.

The highest proportion of oviposition, at Garfield Lake, took place on or before June 17 (Fig. 3, Table 4); whereas there was a leveling of oviposition activity, with minor variations incident to sampling, around June 30 at the Boulder Lookout plot. Inundation is the factor believed to have controlled the difference in susceptibility to heavy defoliation at these sites. Two obvious results of inundation are the effects it has on the larvae, prepupae, and pupae (Lejeune, 1951), and its effects on the host tree. The stand at Garfield Lake alone presented evidence that the latter was an important factor too.

Towards the end of the first week in July, when defoliation was nearly complete on all the susceptible trees in the stand, an "island" of unaffected trees became manifest. This part of the stand was still under water, whereas only scattered pools existed in the defoliated portion of the stand. High water in this stand delayed the onset of shoot elongation past the period of maximum adult activity (Fig. 4). Among the very slow growing bog types the trees are not generally susceptible to larch sawfly attacks. The light injury to tamarack in the Boulder Lookout plot may be attributed to high water which delayed shoot elongation about two weeks. The peak of adult sawfly emergence preceded shoot elongation; consequently the trees in this area escaped heavy defoliation. This phenomenon may be demonstrated by noting the presence of fifth-instar larvae at the Garfield Lake plot on June 17 (Fig. 5), while on June 23 only first- and second- instar larvae were found at the Boulder Lookout plot (Fig. 6). Allowing 8 days for incubation, an average of 10 days is required to produce a second-stage larva, and an average of 20 days is required before the fifth instar is attained.

Branch samples revealed the maximum larval population to be present at Garfield Lake about June 26 when the average number per branch was 283; the maximum was 699, the minimum was 31. At the Boulder Lookout plot the maximum larval population occurred about July 7. The average number of larvae per branch was 28; the maximum was 119, the minimum was 0.

Entomophagous insects and diseases

Consideration of the value of parasites as control agents of the larch sawfly was given great stimulus by the success of the introduced parasite, Mesoleius tenthredinis, in earlier outbreaks (Craiddle, 1928). This introduced parasite readily adapted itself to its host in Canada and the United States and dispersed from points of release with remarkable rapidity within a few years. Credence was given the belief that this parasite could deal a severe blow to a resurgence of the larch sawfly, but studies carried out at the Laboratory of Forest Biology in Winnipeg showed that host resistance had developed in Saskatchewan and Manitoba to so great an extent that the present efficiency of the parasite is seriously impaired (Muldrew, 1950, 1951). In 1952 this phenomenon was reported occurring in Minnesota (Dowden, in press) and preliminary work revealed its presence in Wisconsin. Accordingly, several hypotheses may be pursued: M. tenthredinis may be more important in physiologically weak populations; possibly by selective heredity it may develop a race of parasite that may overcome its predicaments; perhaps both of these forces will act in concert.

There is some evidence pointing toward the first hypothesis. A population in British Columbia, which is currently declining, was annually parasitized over a period of three years in the order of 60 percent, and dissections of prepupae in diapause revealed that nearly 90 percent were parasitized (McLeod, 1952). Muldrew called attention to the idea that host vigor may be one of the factors involved when he stated: "A higher percentage of (Mesoleius) eggs seem to hatch in the more sickly host larvae." (Muldrew, 1951).

Bessa selecta is a larvaevorid parasite whose distribution is general throughout Europe, including the United Kingdom and Russia, as well as in Canada and the United States where it is known to parasitize insects belonging to the sawfly and microlepidopterous groups (Hasboldt, 1947). Overwintering larvae of B. selecta have been reported encapsulated within the larvae of the European spruce sawfly, Diprion hercyniae (Htg.)(Hasboldt, 1947). During the course of larch sawfly dissections, a single specimen of overwintering Bessa larva was noted to be dead within a capsule. The host apparently has the ability of encapsulating other foreign objects, for a hymenopterous ovipositor 3.8 mm. long was removed from a gelatinous sheath.

It is evident that a small proportion of larvae attacked by Nascleius tenthredinis are successfully parasitized (Table 5a). Living Nascleius larvae were found in 2 percent of 664 dissected larvae. This is believed to be a conservative figure, but it is certainly indicative of the low degree of successful attack by this parasite. Sixteen percent of the larvae contained encapsulated Nascleius eggs in 1952, and parasitization attributable to Bessa selecta was 5 percent, while diseases accounted for 4 percent and unknown factors accounted for 11 percent of the sample.

The apparent parasitization of larch sawfly larvae was higher at the Boulder Lookout study plot than at the Garfield plot where defoliation of trees with normal phenological habits was complete (Table 5b). At the former the effective parasitization by Nascleius was 5 percent and at the latter it was only 1 percent. Since the sampling universe was much smaller at Boulder it may very well be that these figures reflect the greater proportional sample than at Garfield Lake. Bessa selecta

appeared in less than 1 percent of the samples at both plots, and a chalcid that attacks larch sawflies in their cocoons, Tritneptis klugii Ratz., may have been the mortality factor in 3 percent of the samples from Boulder Lookout. Butcher reported a high degree of parasitism by Tritneptis in Minnesota, but he ascribed this to the emergence of the parasite from one host cocoon in a lot infesting others (Progress Report, 1949, Milwaukee F. I. L.). Even so, no Tritneptis were recovered from rearings this season. Mortality caused by disease amounted to 0 and 3 percent at Boulder Lookout and Garfield respectively, while losses from unknown factors caused mortality of 9 and 13 percent respectively. One specimen of a rare parasite, Ichneutes bicolor Cress. was recovered from the larch sawfly material collected near Whipholt, Minnesota. This parasite had been collected by Cresson in Massachusetts and described by him in 1872 (Muesebeck, et al., 1951). No additional published records of this insect are known. Another recovery was that of the parasite, Aptesis sp.

Investigation of the diseases affecting the cocooned sawflies was carried out at the Laboratory of Insect Pathology, Sault Ste. Marie, Ontario, Canada. When cocoons were opened and the larvae appeared diseased they were put back into the gelatin capsules and the capsules were labeled for shipment to the Sault Ste. Marie laboratory. The data obtained from the cultures of the suspected specimens are summarized in Tables 5a and 5b. Qualitatively the organisms associated with the larch sawfly cocoons were:

Primary pathogens	(Beauveria bassiana (strain globulifera (red)).
	(Beauveria bassiana (yellow)
	(Isaria farinosa
	(Spicaria sp.
Secondary or Contaminant	(Mucor sp.
	(Penicillium sp.
Bacteria	Resembles Bacillus cereus

Several unidentified organisms were also present.

Rate of oviposition

The Boulder Lookout mite proved to be a poor selection for a rate-of-oviposition study. The possibilities seemed attractive at first, but as the season progressed it was realized that shoot elongation would be delayed on trees growing in this very wet bog; thus precluding the possibility of attaining the objective of the project. It was also found that the weekly branch samples would disclose the desired information. If twigs were not utilized for oviposition until after they developed for about six weeks, they did not form the characteristic curl.

Summarization of the results indicate maximum oviposition occurred on the sample trees between June 26 and July 3. Maximum oviposition activity based on weekly branch samples appears to have occurred there between June 30 and July 7.

In the future, information regarding the rate of oviposition will be collected from the regular branch samples.

Head capsule width

The head capsule width of 20 larch sawfly larvae from each of the five instars was determined, so that temporary employees and others not familiar with the different instars would have a reference available to them for distinguishing the different instars. No overlap in head capsule measurement was evident among larvae of the five instars.

Defoliation vs. cocooning universe

Since tree size varies tree by tree and plot by plot, annual population comparisons should be made for study of defoliation versus the cocooning universe. Serious sources of error have been found while attempting to devise suitable techniques for this study. It is well to describe some of the difficulties attendant to larch sawfly cocoon sampling:

1. Determination of the microsite for making the collection.
2. Selection of "good" cocoons from those in which the larvae probably drowned - this pertains to springtime collections.
3. Avoidance of rodent caches.
4. Separation of current from old and/or parasitised cocoons.
5. Type of sample - i. e. by area or length of time.

Cocoon collections were made late in the summer of 1952. They were based on time - 10 minute collections under the crown periphery of three trees used for defoliation studies. Depressions with standing water in them were avoided whenever possible. Defective cocoons were rejected from the sample as these were generally found in rodent caches

or had holes indicating parasite or predator activity. Cocoons that were dark might be either old cocoons or new cocoons which had been in standing water. At some plots rodent activity had already reduced the cocooning universe by the time the collections were made.

In order to overcome some of the problems besetting this phase of the investigation, six minute collections will be made in 1953 under each of the 10 "defoliation trees" and attempts will be made to collect this information somewhat earlier in the season. Comparative data will be omitted here pending additional collections.

Larval development under insectary conditions 1/

Determination of the period spent in the various instars and the quantities of frass produced in these larval stages are basic to the understanding of the ecology of defoliating insects. Specifically, information from this study is applicable to the timing of other work associated with the larch sawfly.

A report on this type of study has already been published (Heron, 1952), but his results were not available at the time the writer undertook the project in Minnesota.

Larvae in the first three instars required from slightly more than 2 days to slightly more than 3 days per stadium (Fig. 7, Table 7), while development in the fourth and fifth instars took approximately 4 to 6 days. Considerable variation existed in the amount of time passed in each stadium.

1/ This information was developed by L. C. Beckwith, while he was a temporary scientific aide on the larch sawfly project.

The voracious fifth-instar larvae produced more than 80 percent of the total weight (oven-dry weight) of frass, and only about 5 percent was produced by larvae in the first 3 instars while a little more than 12 percent came from the fourth-instar larvae (Fig. 8).

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APPENDIX

Table 1. - Influence of maleic hydrazide-40 on tamarack shoot elongation in Minnesota in 1952.

Tree No.	Conc. MH-40 percent (by weight)	Dose per tree (in ounces)	Height of tree (in feet)	Number of shoots 1951	Number of shoots 1952	Average Number of shoots 1951	Average Number of shoots 1952
1	0.333	10	4.6	42	65		
2	0.333	10	5.0	55	25	52	67
3	0.333	10	5.1	59	110		
4	0.250	10	9.3	323	213		
5	0.250	10	6.6	197	127	218	174
6	0.250	10	5.7	134	182		
7	0.125	10	6.3	120	47		
8	0.125	10	8.3	71	72	108	92
9	0.125	10	5.3	121	157		
10	0.000	0	8.3	121	156		
11	0.000	0	5.4	41	24	106	122
12	0.000	0	9.0	156	187		

Table 2. Comparison of larch sawfly frass-drop and number of fifth instar larvae at Garfield Lake plot.

Date	Number fifth instar larvae per 10 branches	Average Weight of Frass (O.D.W. - Mg./ Sq. Ft.)
June 17	201	
" 20		0.296
" 26	566	0.730
July 4	522 1/	
" 5		1.514
" 10	169	0.200
" 11		

1/ Many larvae lost in transport.

Table 3. Frass-drop Analysis - Boulder Lookout - Near Bena, Minn. - 1952

Plot Number 1/	Mg. of Frass per 2 sq. ft. Trap "A"	Trap "B"	Mg. of Frass per 4 sq. ft. Total = A + B	Mean A + B
1	2304	1330	3634	1817
2	2983	2251	5234	2617
3	7841	5234	14167	7084
4	5360	7254	12614	6307
5	9050	8905	17955	8977
6	1064	3473	4537	2268
7	7561	7418	14979	7490
8	6266	4425	10691	5346
9	0185	0142	327	164
12	6978	0411	7389	3694
13	0884	0638	1522	761
14	25418	30283	55701	27850
15	9590	8646	18236	9118
Total	85284	81702	166986	83513
Mean	6560	6285	12845	6424

Analysis of Variance

Source of Variation	DF	SS	MS	F	Significance
Between Plots	12	1,214,638,864	101,219,905	31.595	Highly Signif. difference Between plots
Within Plots	13	41,648,106	3,203,700		
Total Variation Among Lines	25	1,256,286,970			

	Total Frass Mg. per 2sq.ft.	Mean Frass Mg. Per 2 sq.ft.	Stand. Deviation	Coef. of Var. Percent	S.E.	S.E. of Diff.	Diff. Between Mean A & Mean B ± S.E.d
Trap A	85284	6560	± 6512	99.27	± 1809		
Trap B	81702	6285	± 7890	125.54	± 2192		±0.10SD
A + B	166986	12845	±11228	110.76	± 3952		

1/ Trees constituting plots 10 and 11 died due to inundation and subsequent attack by Dendroctonus simplex.

Table 3 (continued). Frass-drop analysis - Garfield Lake - near Laporte, Minn. - 1952

Plot Number	Nr. of Frass per 2 sq. ft. Trap "A"	Nr. of Frass per 2 sq. ft. Trap "B"	Nr. of Frass per 4 sq. ft. Total - A + B	Nr. of Frass per 4 sq. ft. Mean A + B
1	27996	28874	56870	28435.0
2	38753	36695	75448	37724.0
3	40267	56713	97880	48940.0
4	47828	44045	91873	45936.5
5	40716	47263	77979	38989.5
6	38700	40391	79091	39545.5
7	33961	36430	70391	35195.5
8	32671	35630	68301	34150.5
9	47038	56556	103594	51797.0
10	37663	40331	77994	38997.0
11	62017	56413	118430	59215.0
12	41693	32870	74563	37281.5
13	31500	30062	61562	30781.0
14	46785	38108	84893	42446.5
15	48421	48374	96795	48397.5
Total	616009	619655	1235664	617832.0
Mean	41066.7	41310.3	82378	41188.8

Analysis of Variance

Source of Variation	DF	SS	MS	F	Significance
Between Plots	14	1,939,397,835	138,528,417	9.572	Highly Signif. Diff. Between plots
Within Plots	15	217,078,230	14,471,882		
Total variation among lines	29	2,256,476,065			

	Total Frass Nr. per 2 sq.ft.	Mean Frass Nr. per 2 sq.ft.	Stand. Deviation	Coef. of Frass	Standard Error	Standard Error of Difference	Diff. between Mean A & Mean B ± SE$_d$ ±0.07 S.D. ±0.07 S.D.
Trap Line A	616009	41066.7	± 9610	23.47	±2491	±3523	
Trap Line B	619665	41310.3	± 9118	22.80	±2434		
	1235664	82378.	±16645	20.20	±4301		

Table 4. - Average number of curled tips and larvae present per branch on 10 branch samples collected at approximately weekly intervals.

GARFIELD LAKE - complete defoliation

Date	Number of 1952 shoots	Number of curled tips	Number of larvae by instars: first	second	third	fourth	fifth
June 17	133	39	48	28	48	36	20
June 26	103	40	46	66	78	36	57
July 4	55	25	2	12	31	14	53

BOULDER LOOKOUT - about 30 percent defoliation

Date	Number of 1952 shoots	Number of curled tips	Number of larvae by instars: first	second	third	fourth	fifth
June 15	140	1	0	0	0	0	0
June 23	164	2	16	4	0	0	0
June 30	191	3	7	6	2	trace	1
July 7	141	5	7	1	6	8	7
July 15	115	2	0	3	1	2	1
July 21	147	3	1	0	2	1	3
July 28	97	3	1	0	0	trace	trace
Aug. 4	117	4	0	0	0	0	0

Table 5a. - Summary of the effects of parasites and unknown factors at larch sawfly plots in northern Minnesota 1/

Plot	Location T. N.-R. W.-S	Unattacked		Encapsulated Napoleon eggs		Unattacked plus encapsulated Napoleon eggs		MORTALITY FACTORS									
								Parasites		Ants		Other		Disease		Unknown	
		No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
1	16-37-21	23	77	2	6	25	83	-	-	2	6			1		2	
2	159-31-12	27	90	-	-	27	90	-	-	-	-			0		3	
3	154-30- 9	14	46	6	20	20	67	1	4	1	4			5		3	
4	149-31-29	26	87	-	-	26	87	-	-	-	-			1		3	
5	148-28-18	18	60	4	13	22	73	-	-	2	7			2		4	
6	141-30- 3	18	60	5	16	23	77	3	10	2	7	1 2/	4	1		0	
7	142-28-14	25	83	1	3	26	87	-	-	2	7			0		2	
8	145-25-13	26	86	2	7	28	93	-	-	-	-			0		2	
9	147-25- 1	24	80	3	10	27	90	1	3	-	-			0		2	
10	65-19-29	18	60	1	3	19	63	-	-	1	3			3		7	
11 1/	62-18- 6	7	33	1	5	8	38	-	-	8	38			4		1	
12	60-17-22	17	57	10	33	27	90	-	-	1	4			0		2	
13 1/	59-15-22,23	7	29	8	29	15	57	3	10	1	4			3		6	
14 1/	60-15-12	15	54	6	21	21	75	-	-	1	4			1		5	
15	62-12-8 ,17	16	53	5	17	21	70	-	-	4	13			0		5	
16	55-11-18	20	67	4	13	24	80	1	3	-	-			1		4	
17	58-10-32	19	63	8	27	27	90	-	-	-	-			2		1	
18 1/	60-10-27	10	59	6	35	16	94	-	-	1	6			0		0	
19	59- 8-27	23	77	1	3	24	80	2	7	-	-			2		2	
20	59- 6- 2	14	47	4	13	18	60	3	10	-	-			1		8	
21	62- 4- 7	12	40	9	30	21	70	2	7	1	4			3		3	
22	65- 4-24	10	33	10	33	20	67	-	-	4	14			0		6	
23	63-1E-34	20	67	8	27	28	93	-	-	1	4			0		1	
TOTAL		409		104		513		16		32		1		30		73	
Average		18	62	4	16	22	78	1	2	1	5	T 3/	T	1	4	3	11

1/ Based on dissection of 30 cocoons except for the following plots: 11, 21 cocoons; 13, 28 cocoons; and 18, 17 cocoons. Total cocoons dissected - 664.

2/ (Ichneutes bicolor)

3/ Trace - less than 0.5 percent.

Table 5b.--Summary of the effects of parasites and unknown factors at two larch sawfly study plots in northern Minnesota

Location	Number dissected	Unattacked		Encapsulated Nasoleius Eggs		Unattacked plus encapsulated Nasoleius eggs		Nasoleius Pct.	MORTALITY FACTORS							
									Eggs		Other		Disease		Unknown	
		No.	Percent	No.	Percent	No.	Percent	No. Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Boulder Lookout	140	71	50	22	16	93	66	7 5	1	1	24 1/ 32/	19	0	0	12	9
Garfield	225	161	80	3	2	184	82	3 1	1	T 3/	0	0	7	3	30	13

1/ 24 drowned.

2/ Possibly Tritneptis klugii.

3/ Trace - less than 0.5 percent.

Table 6. - Larch sawfly head capsule widths [1/]

Instar [2/]	Width (mm.) Mean	Maximum	Minimum	Standard deviation ±	Standard error ±	Coefficient of variation percent
1	0.57	0.59	0.53	0.018	0.004	3.18
2	0.80	0.84	0.74	0.027	0.006	3.36
3	1.16	1.20	1.12	0.019	0.004	1.64
4	1.62	1.68	1.58	0.035	0.008	2.14
5	2.12	2.18	2.05	0.037	0.008	1.73

1/ Specimens collected near Cass Lake, Minn., June, 1952.

2/ A sample of 20 larvae per instar.

Table 7. - Stadium duration and frass yield per larval instar [1/]

Instar	Duration of stadium (days) Mean	Range	Frass Yield (Mg. - O. D. W.) Average per larva	Standard Deviation ±	Percent of total
1	2	2 - 3			
2	3	2 - 4	12.7	2.5	5.3
3	2	2 - 3			
4	4	4 - 5	29.6	4.6	12.3
5	6	5 - 6	197.6	20.7	82.4

1/ This information was developed by L. C. Beckwith, while he was a temporary scientific aide on the larch sawfly project.

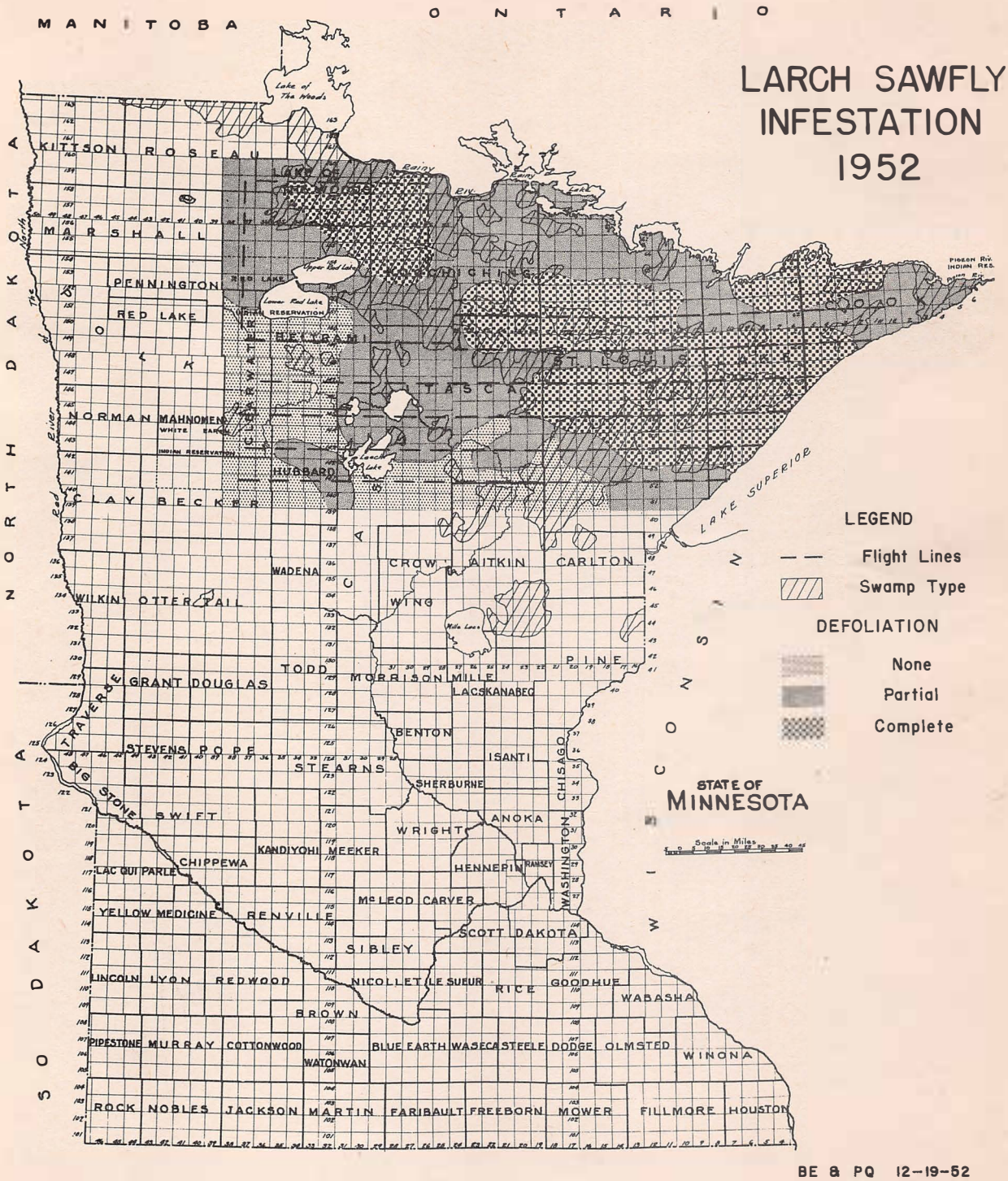

Figure 1. Principal outbreak area and defoliation intensity based on the 1952 aerial survey.

U.S.D.A. - S.C.S. Milwaukee, Wis., 1952

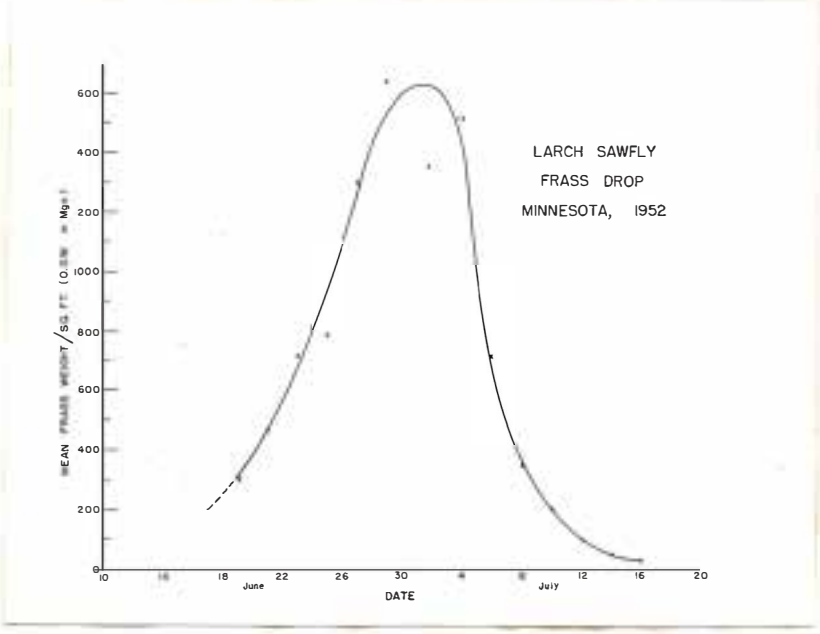

Figure 2. - Frass-drop based on data from trap studies at Garfield Lake plot.

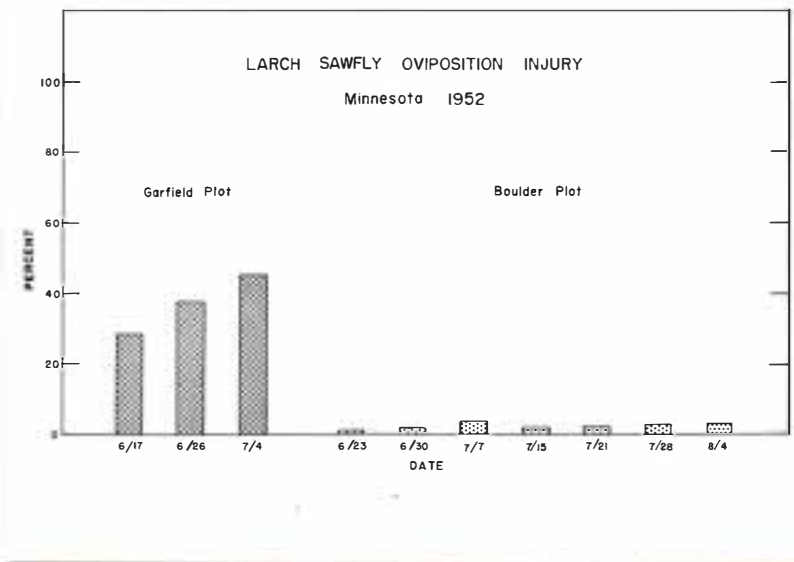

Figure 3. - Percent of oviposition injury based on total number of 852 shoots present per collection. Complete defoliation occurred at Garfield and about 30 percent defoliation took place at Boulder.

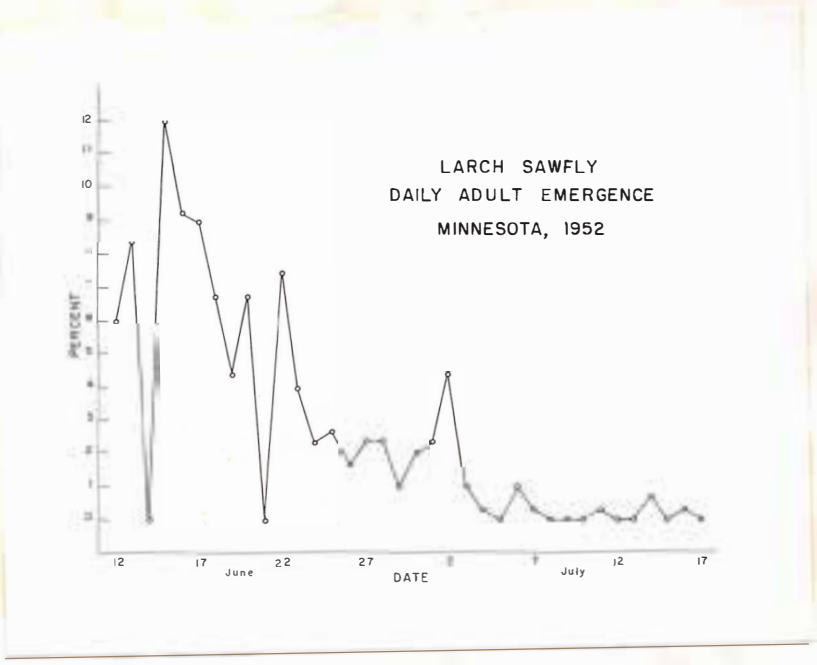

Figure 4. - Daily record of adult emergence. Percentages are based on total number of "good" cocoons.

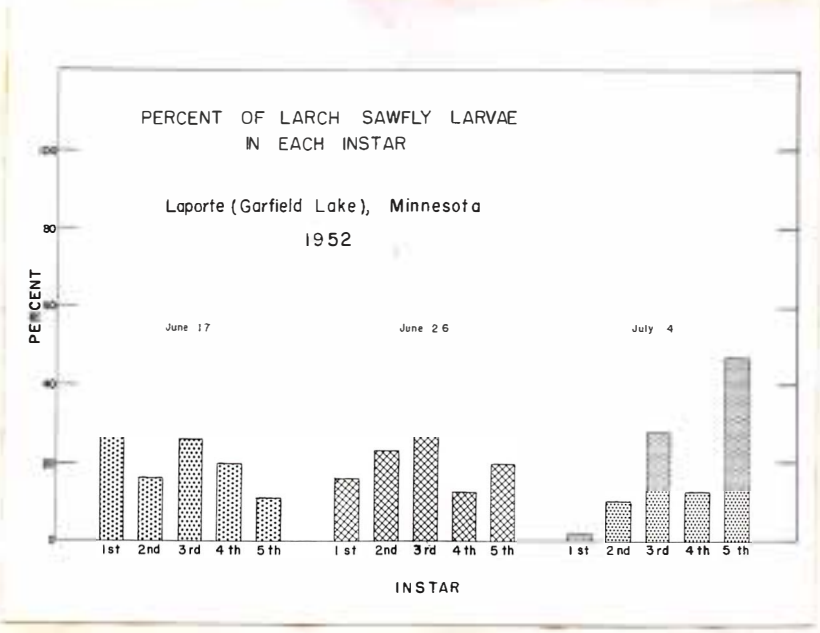

Figure 5. - Progress of larval development at Garfield where shoot elongation was unimpeded. Percentages are based on total number of larvae per collection.

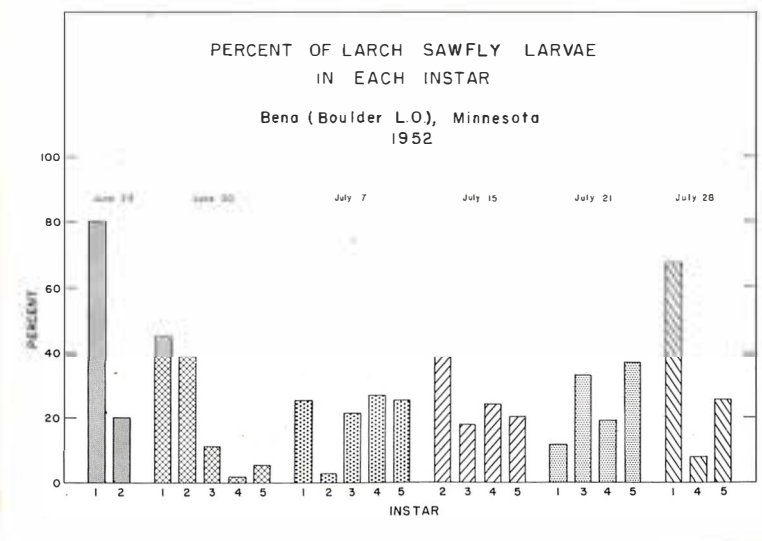

Figure 6. - Progress of larval development at Boulder where high water prevented tamarack shoots from expanding at normal time. Percentages are based upon total number of larvae per collection.